ITk Strip Module Production Status

Reporter: Yuzhen YANG
on behalf of IHEP/THU ATLAS Itk group

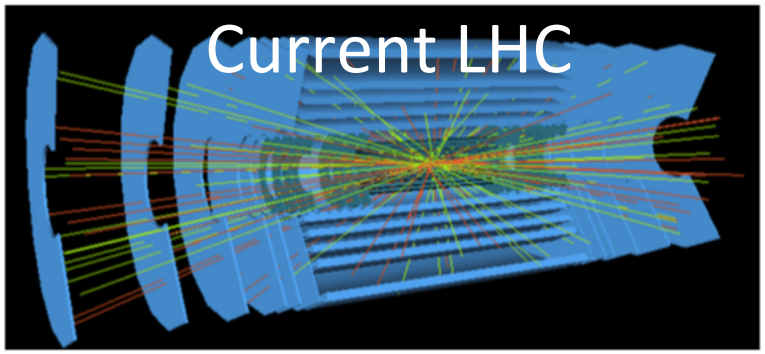
Outline

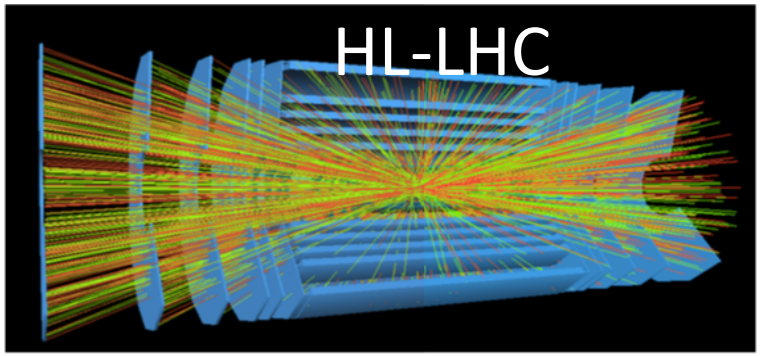
- Introduction
- Module production at RAL
  - ABC130 module/stave
  - ABCStar module
  - Sensor bowling study
- Module Production at IHEP/THU
  - Clean room status
  - Assembly
  - Electrical test
- Wire bonding
- QA/QC process
- Summary

ATLAS Inner tracker (ITk) for HL-LHC

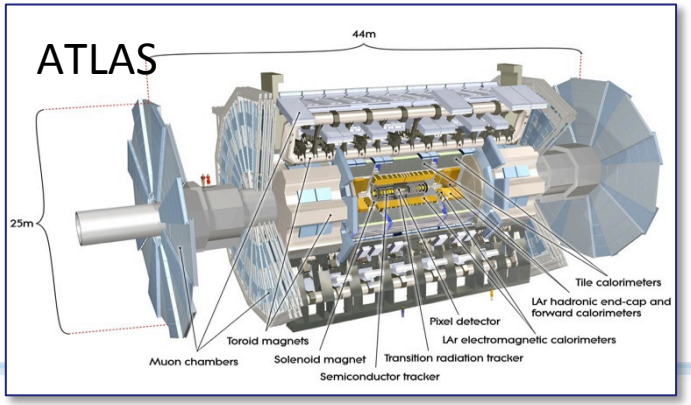
High Luminosity-LHC (HL-LHC) is foreseen to be completed in 2026.

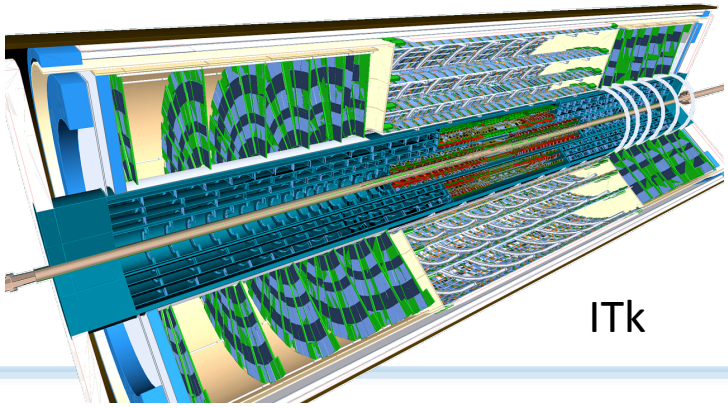
- Aim to increase the integrated luminosity to ~ ten times the original LHC design.
- Improve the precision of Higgs measurement, better sensitivity to new physics.





Inner Tracker (ITk) will replace ATLAS current semi-conductor tracker (SCT) to improve resolution and solve signal pile-up.



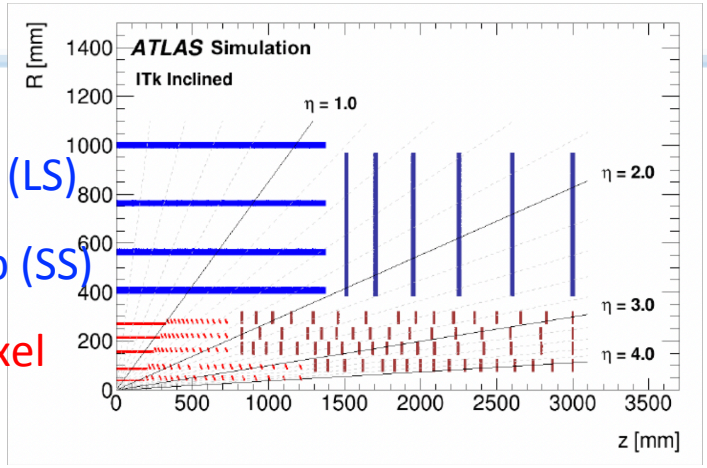


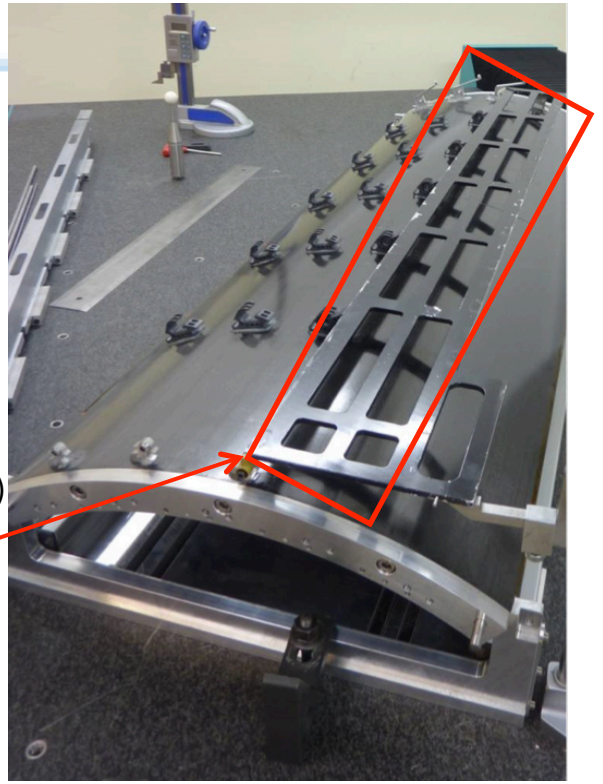
ITk Barrel Strip Detector

Long Strip (LS)

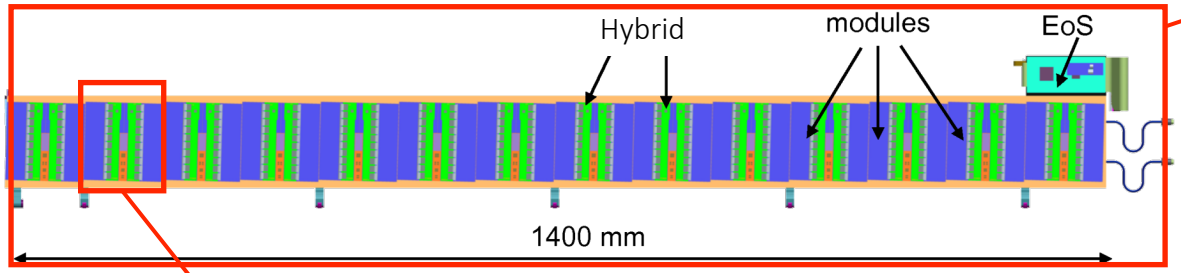
Short Strip (SS)

Pixel

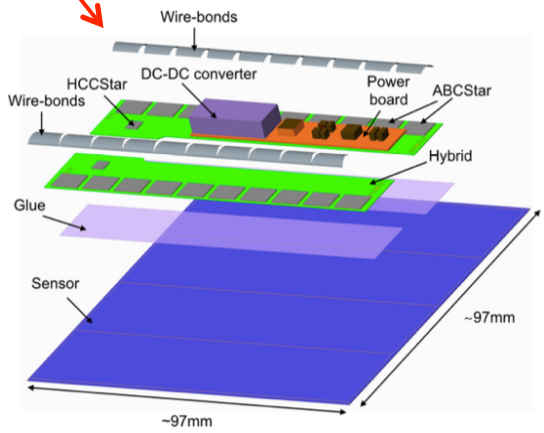


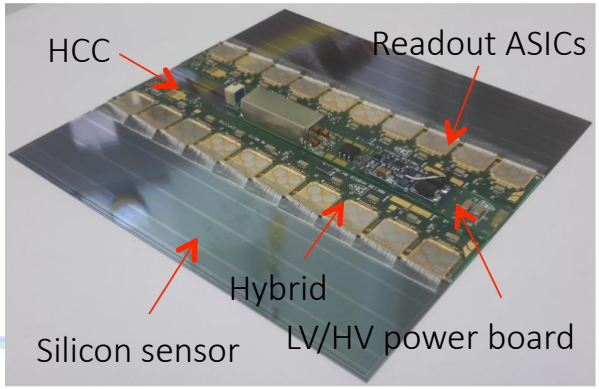


Stave = 28 modules + electronic (bus tape) + thermal (cooling pipe) + mechanics (carbon fiber)



Module

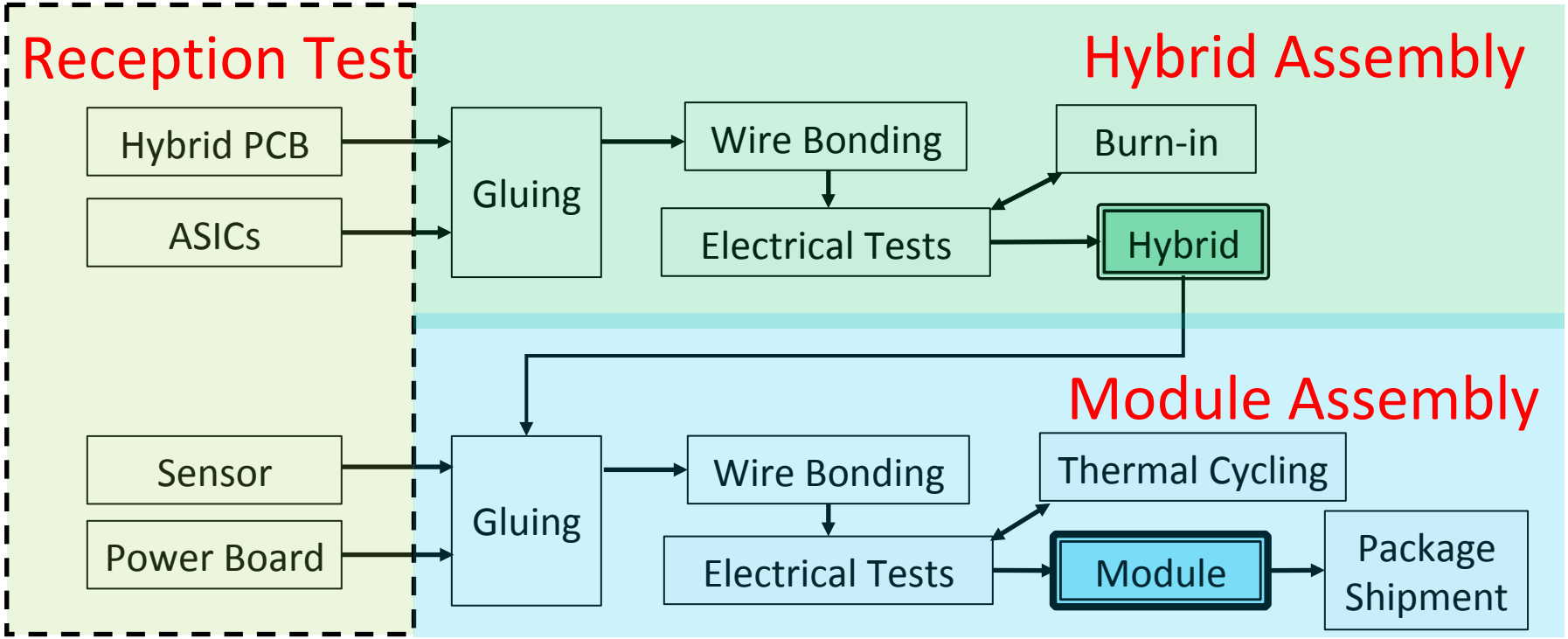




IHEP/THU will contribute 1000 barrel strip modules (10 m^2 silicon) for ITk.

Strip Module Assembly

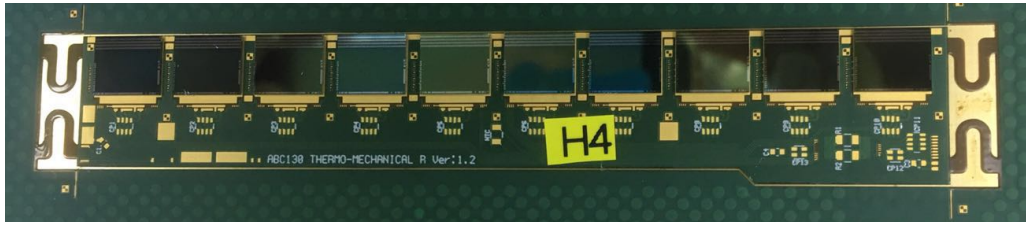
Hybrid details see Dengfeng's slides.



- Low-mass Kapton hybrid with ABCStar (ATLAS Binary Chip) and HCCStar (Hybrid Controller Chip) ASICs
- Power-Board including DC-DC Low Voltage (LV) Power Block, monitoring ASIC , and HV multiplexer

Module Assembly process

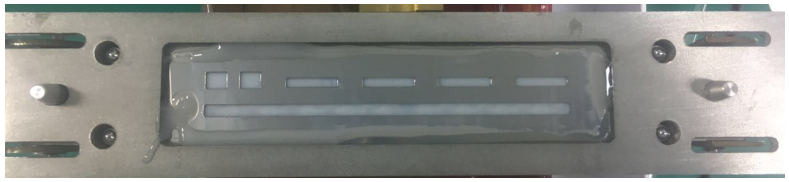
1. Assemble hybrid, pick up hybrid using picking-up tool

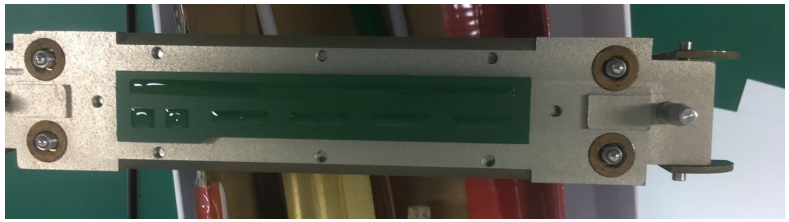


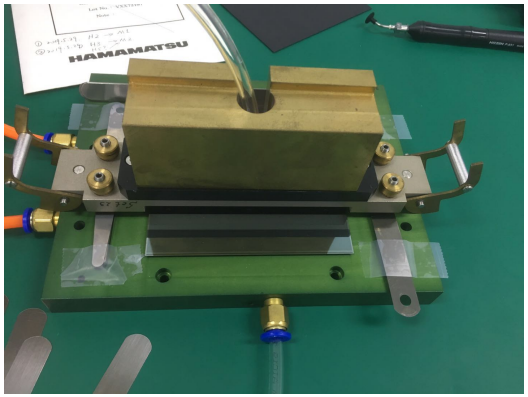
2. Load sensor on work holder, set tools for 120um thickness glue using shim

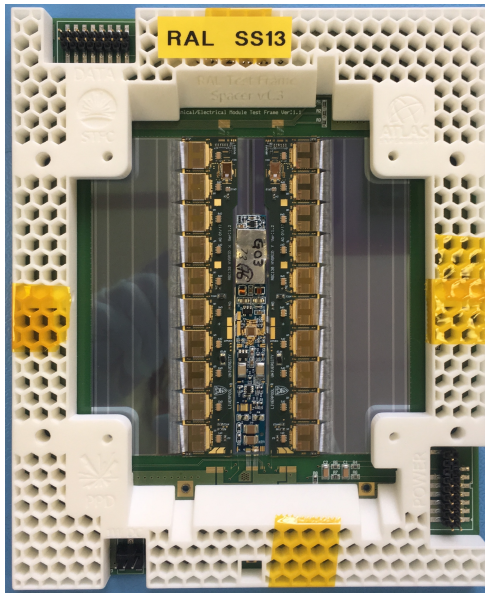
3. Mix two component of epolite glue

4. Spread glue on the top of stencil







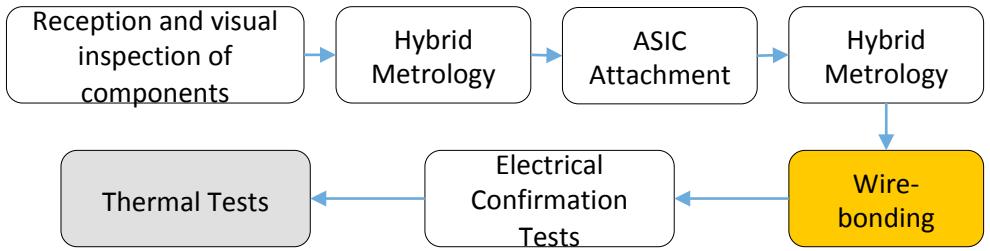


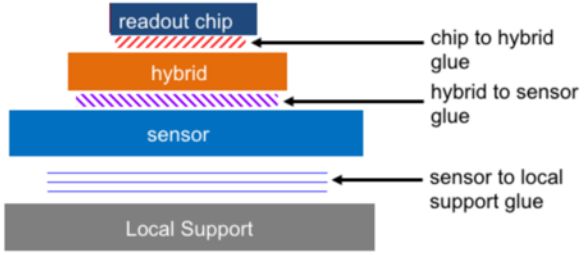
5. Move hybrid on sensor, put on weight, wait 24 hours for curing

Quality Control

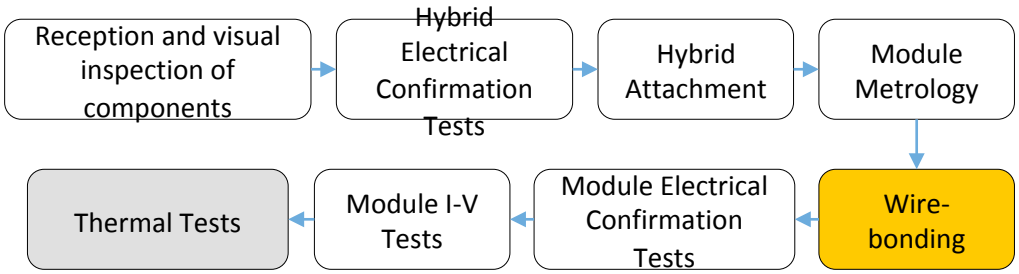
Based on the prototype study, along with the current ATLAS SCT detector experience, improve the quality control (QC) of module production process.

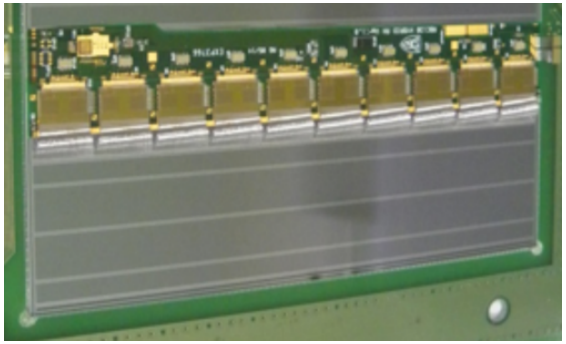
Hybrid QC



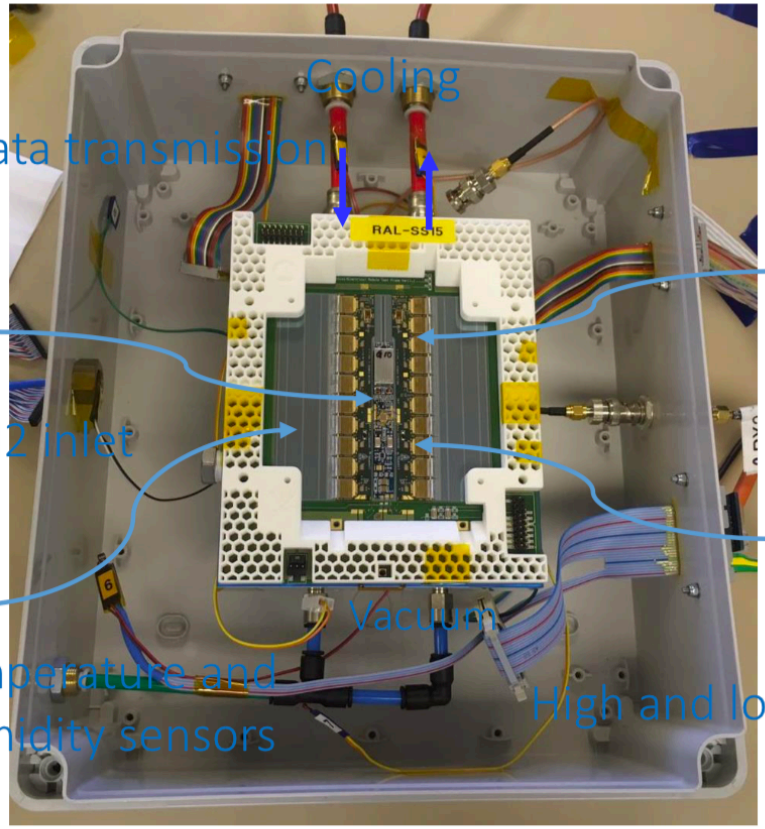


Detector Module QC





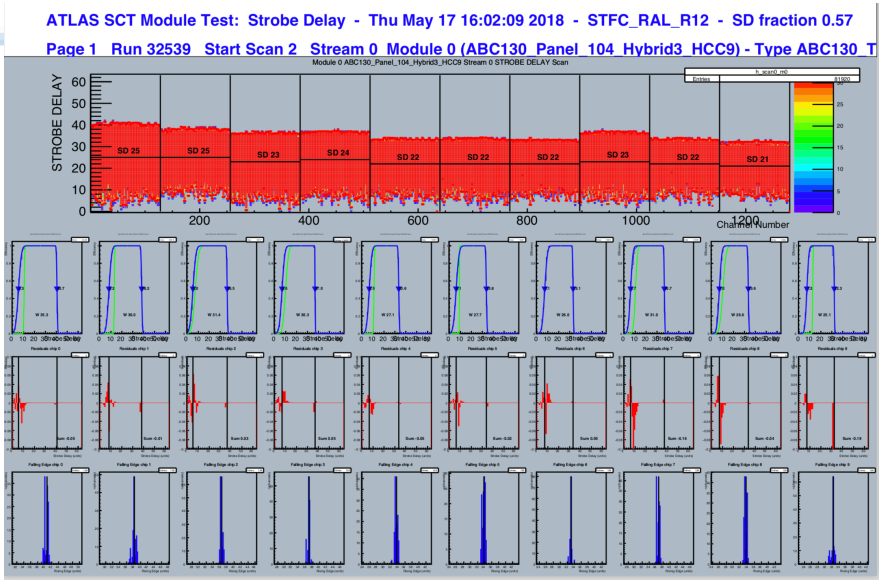
MODULE TESTING @ RAL

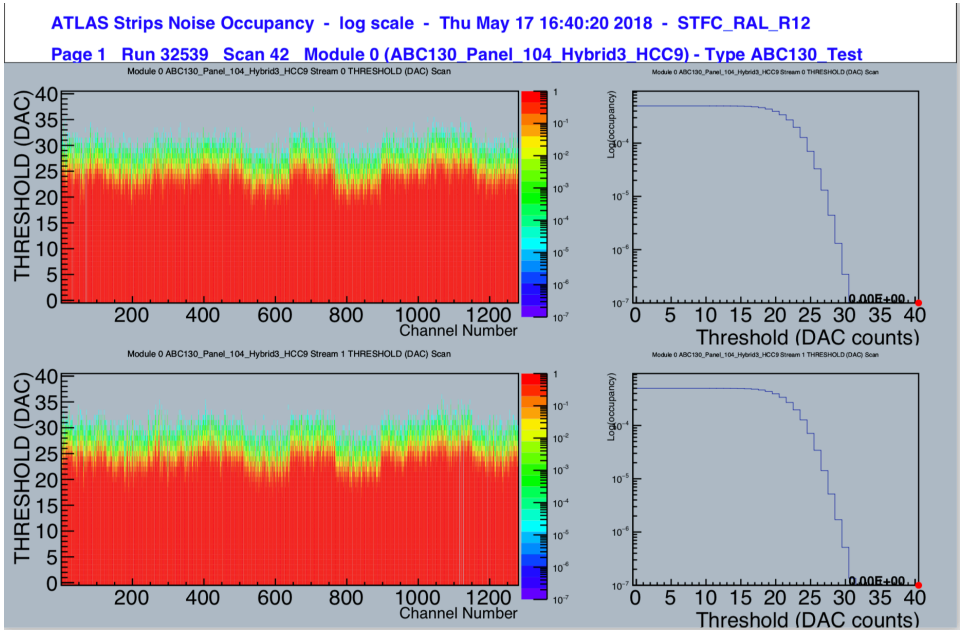


- Reception tests of assembled modules before loading them onto the stave → to complete the 130 program (hybrids/modules assembled with ABC/HCC-130 ASICs)

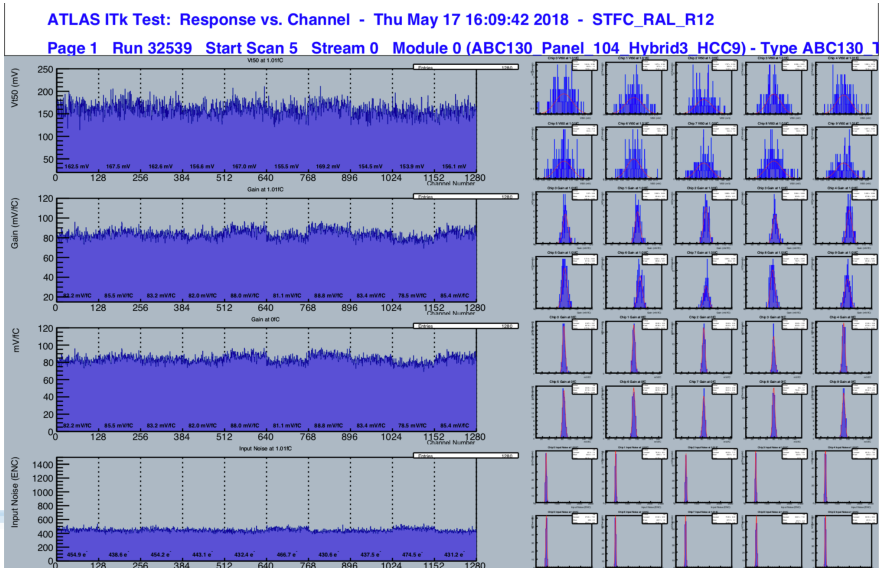
Electric test result

Strobe delay





Noise occupancy



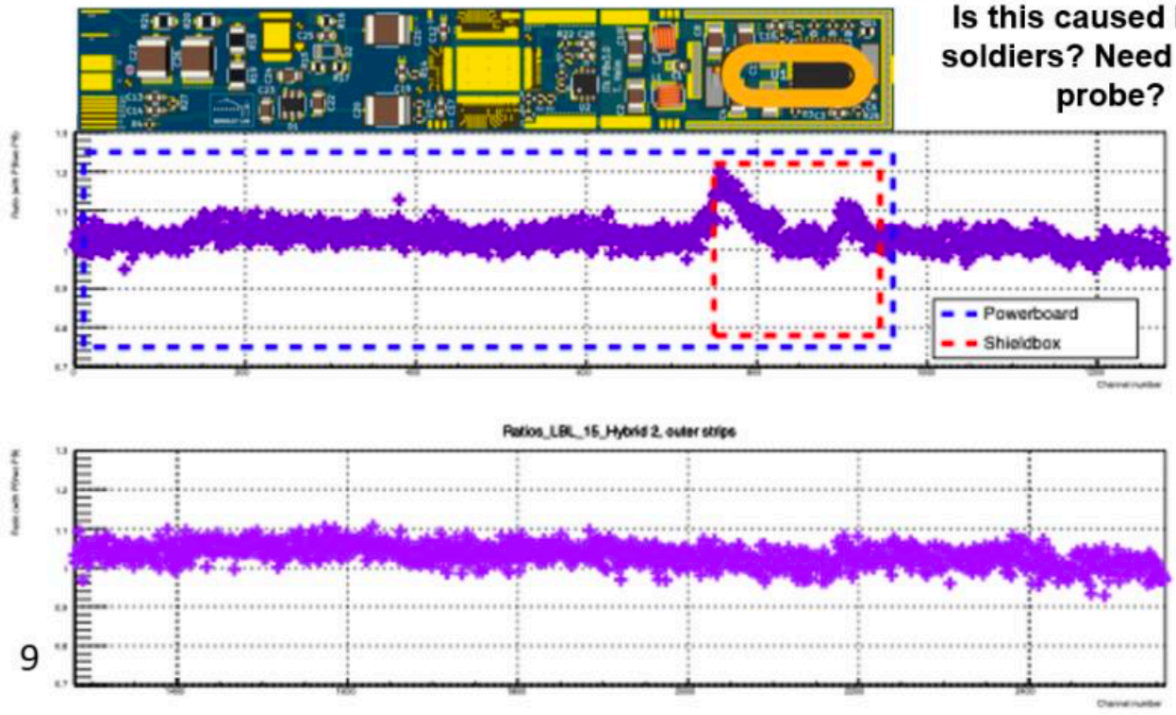
Response curve

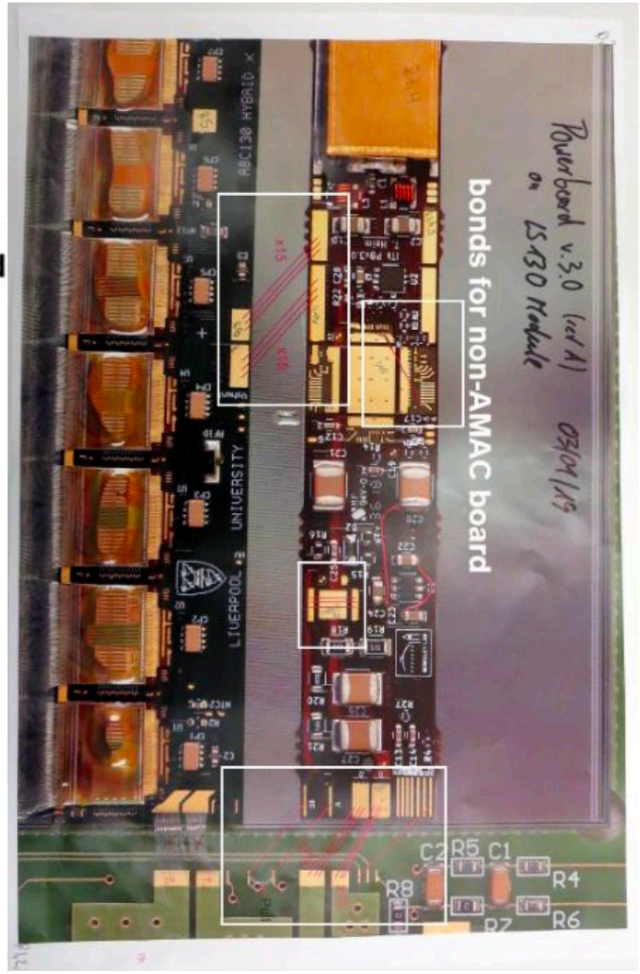
POWER BOARD TESTING

Boyang Li's (Tsinghua) work during his visit to LBL

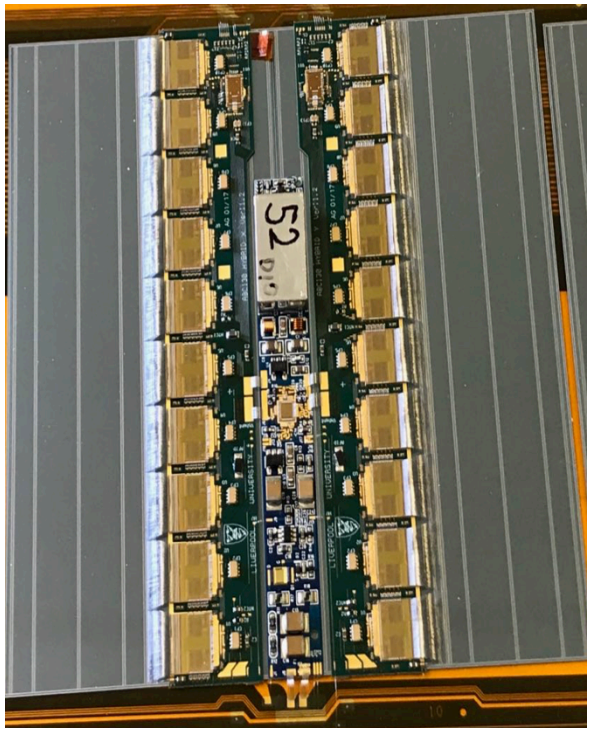
After/Before

There are 2 peaks around the coil
Is this caused by the soldiers? Need B field probe?





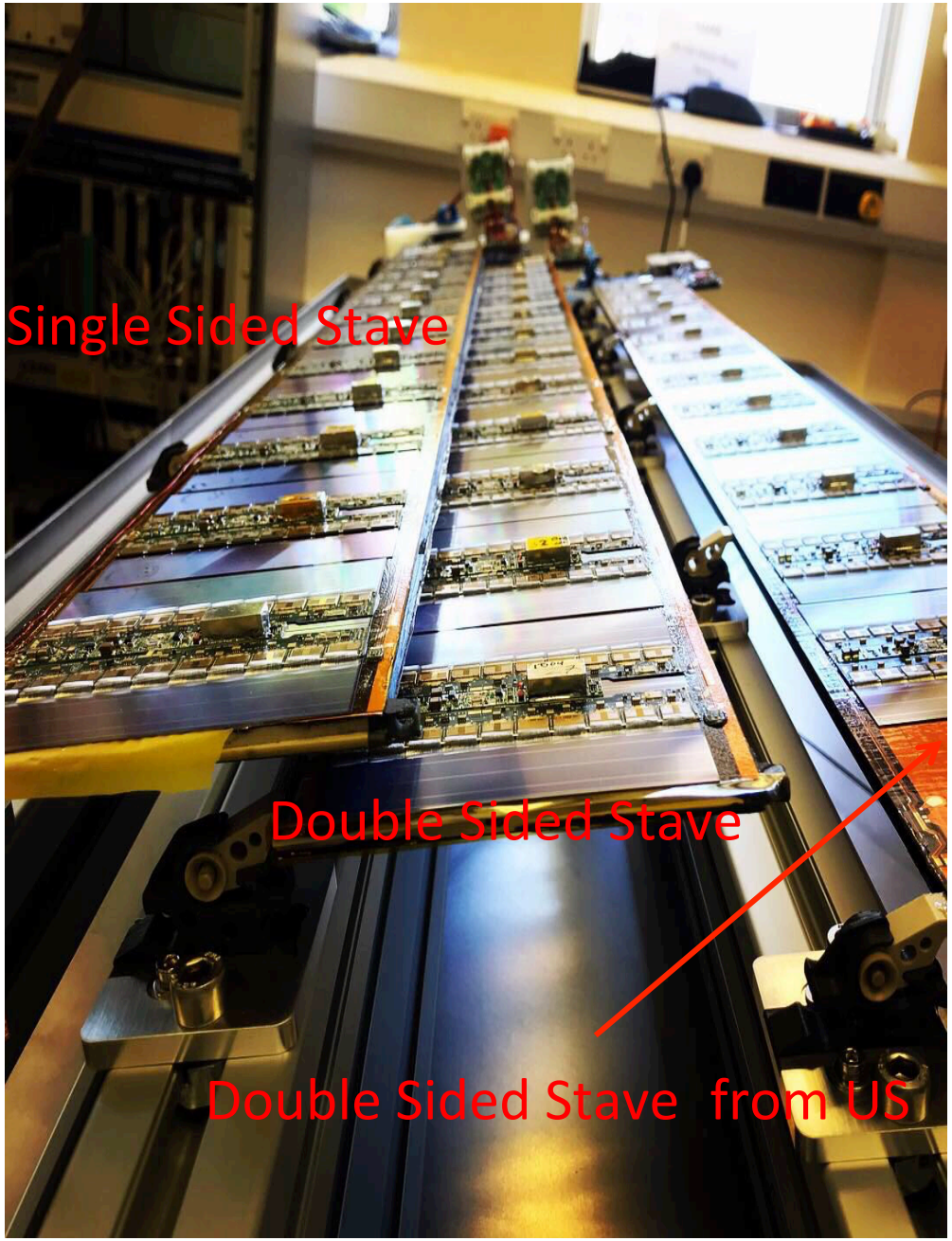
Module at RAL



stave at RAL -- >

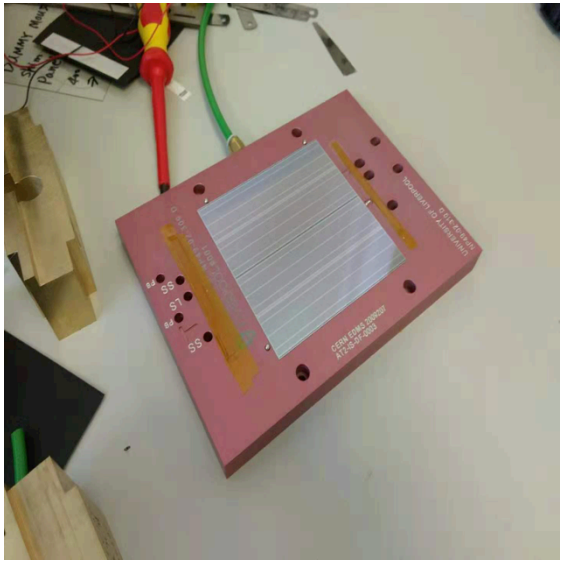
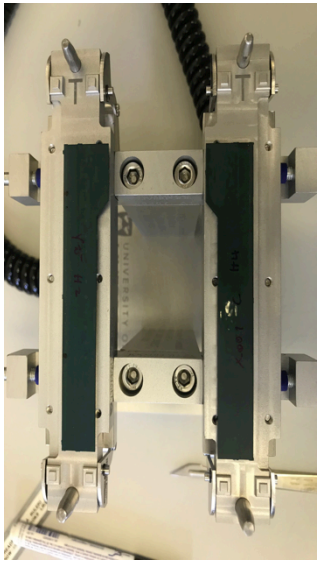
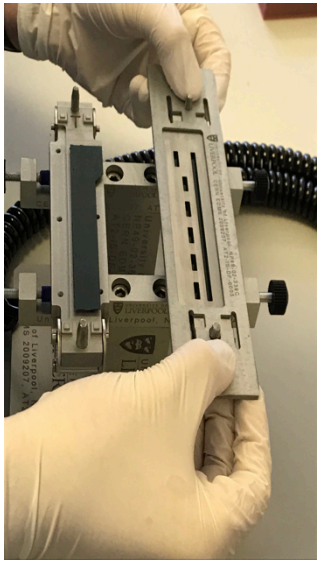
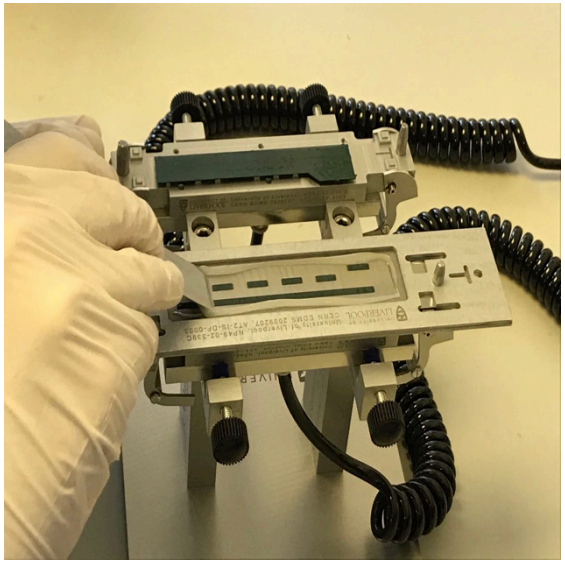
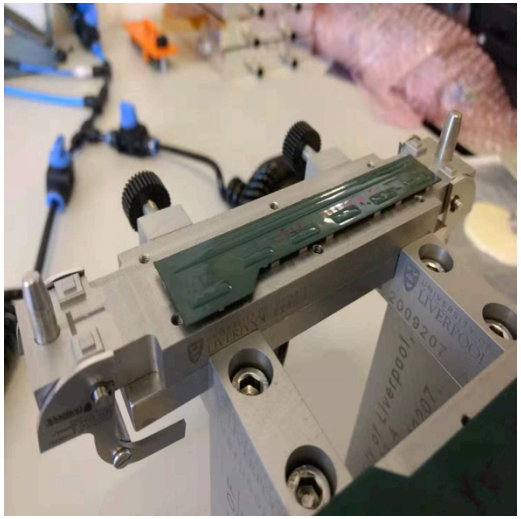
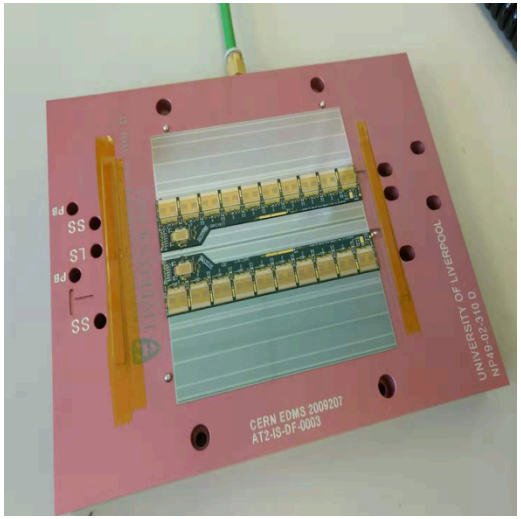
For Crosstalk Testing
(Electromagnetic Interference)

Emma and Matt working at RAL



Emma and Matt working at RAL

ABCStar module assembly process (at RAL)

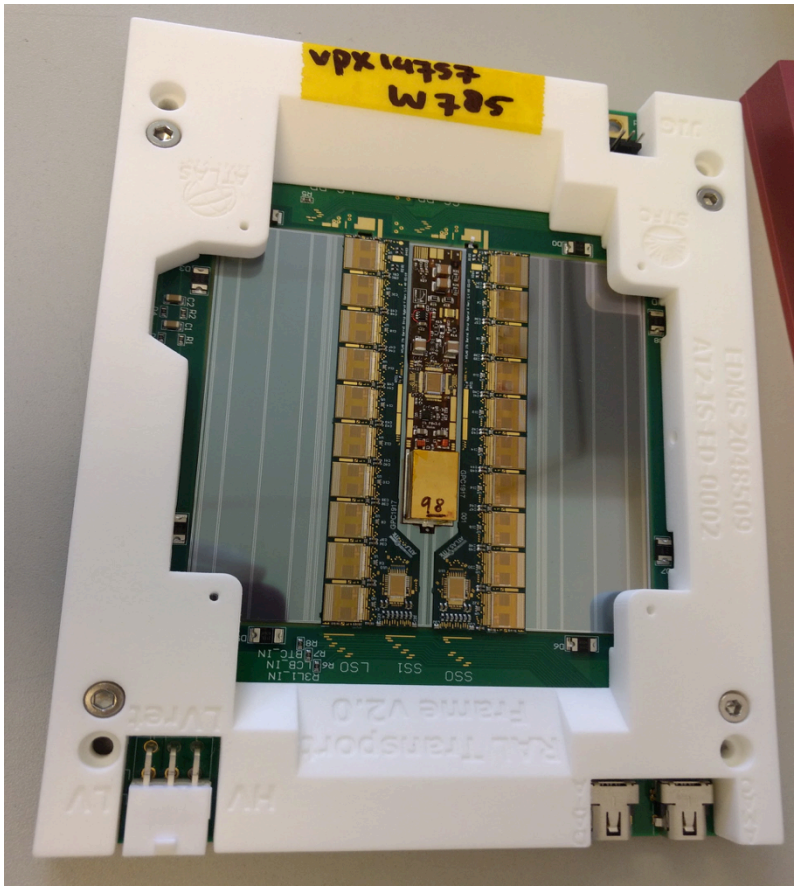







- Sensor placement
- Hybrid pickup
- Hybrid glue stenciling
- Hybrid to sensor gluing with 12 hour cure
- Power board freehand gluing

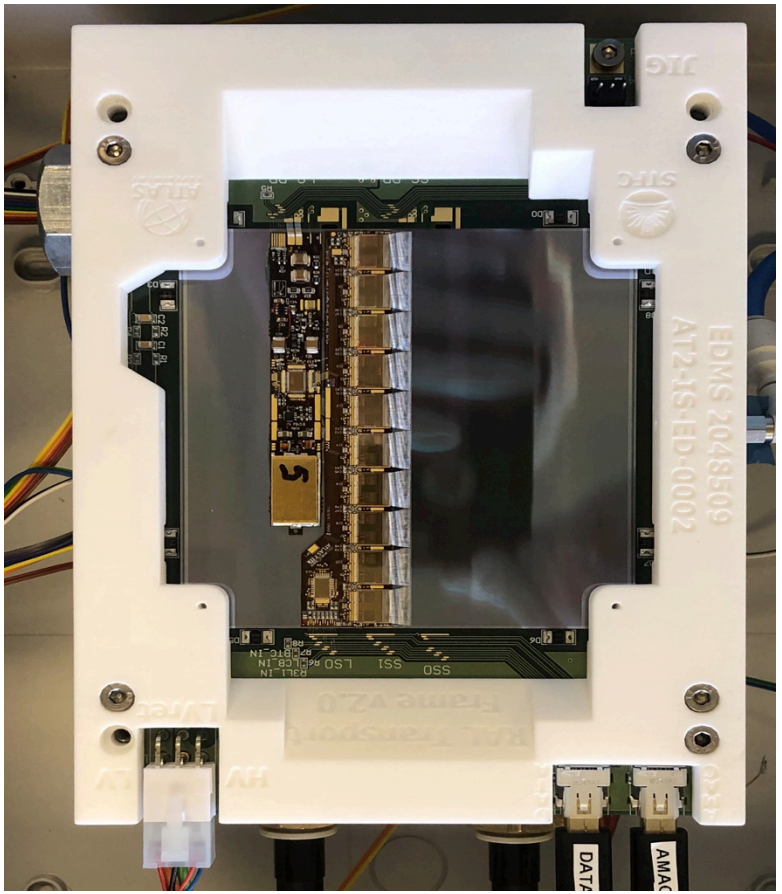
Emma and Matt working at RAL

SS and LS ABCstar Modules

Short Strip Module



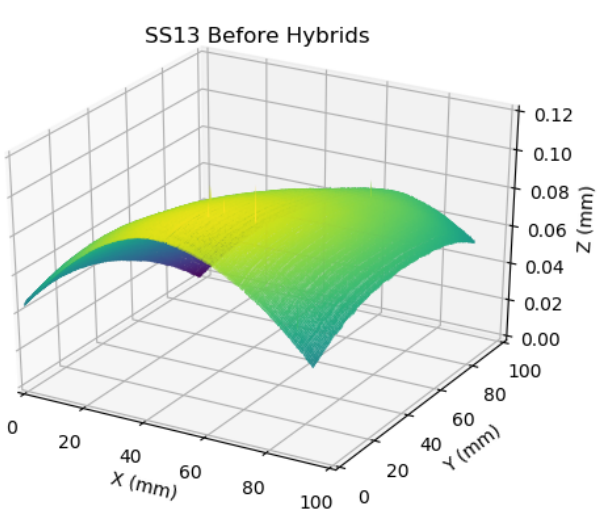
Long Strip Module



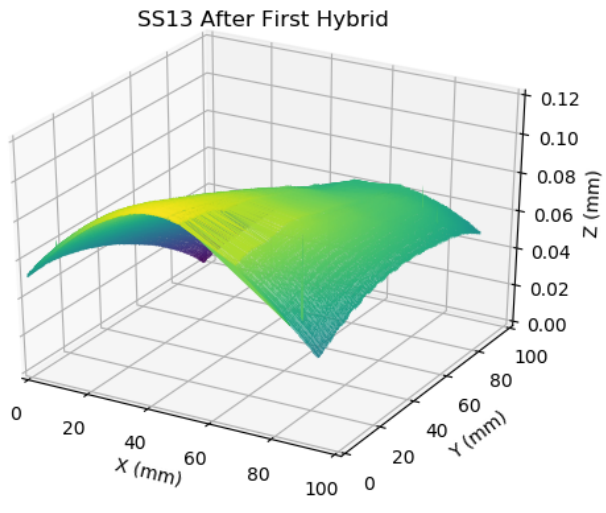
Matt working at RAL

Sensor Bowing Study

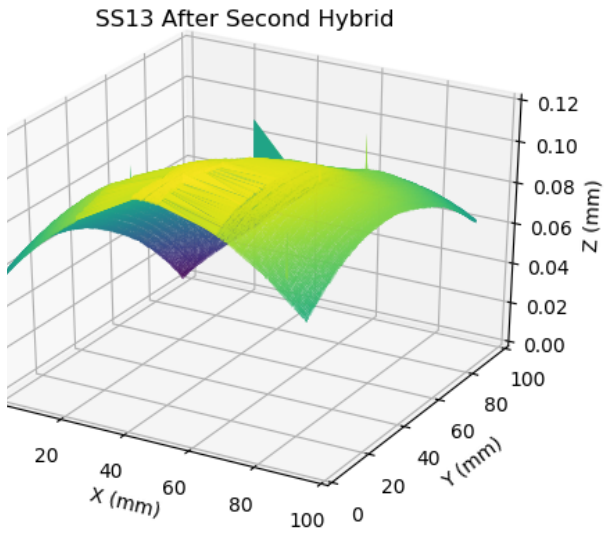
- Scanned surface using white light interferometer at 200 um intervals in x and y directions to find height of surface
- Z resolution of less than 1 um
- 225k height measurements per sensor



Before glue hybrid



After 1st hybrid



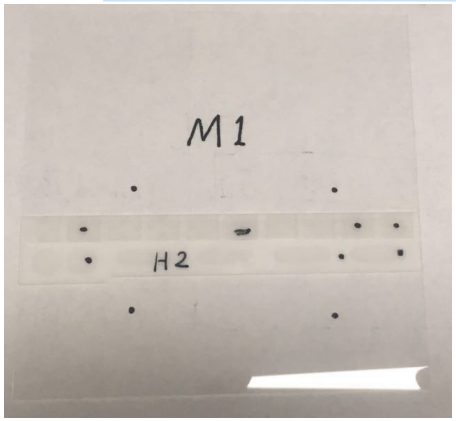
After 2nd hybrid

- Test 4 sensor before gluing hybrid: bowing between 50 and 100µm
- Bowing increases by 25-35 µm after the hybrids are glued on the sensors
- Production sensors won't have an initial bow as much as these sensors and the additional 25-35 µm is within the production tolerance

IHEP Clean room

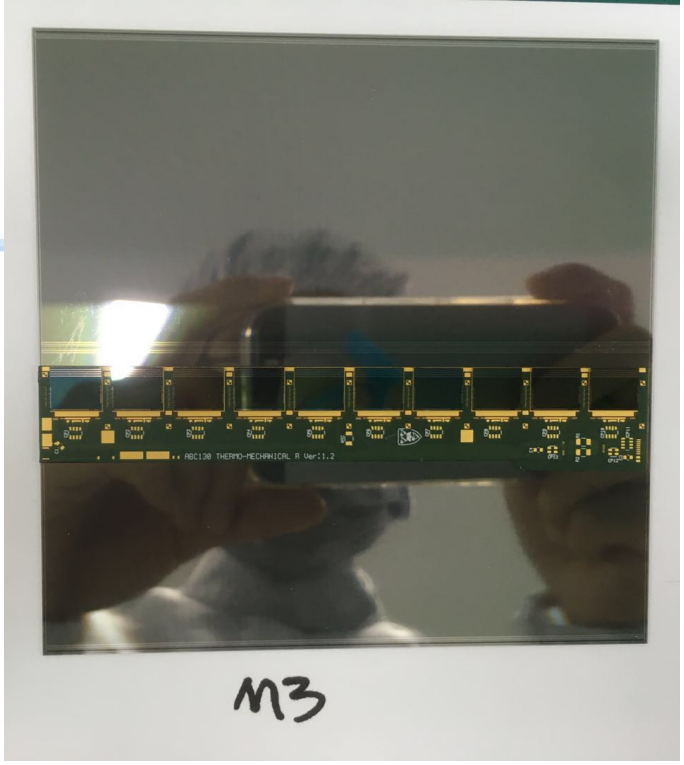
80m^2 Class 10,000 clean room being constructed
→ dedicated for the ATLAS strip module production

Module made in IHEP



Dummy module M1

Dummy module M2



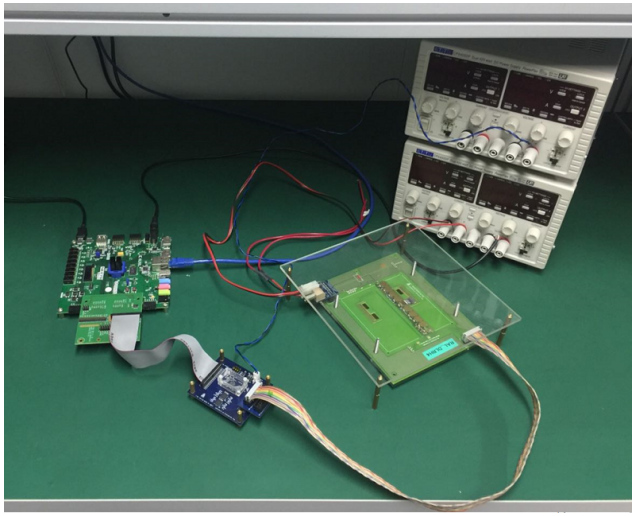
Mechanical module M3

Type of module	No	Sensor	Hybrid	ASIC	Thickness of glue/um	Time
Dummy module	M1	Glass	Plastic	Glass	76~113	20190529
Dummy module	M2	Glass	Plastic	Silicon	127~145	20190530
Mechanical module	M3	Silicon	Mechanical	Silicon	105	20190531

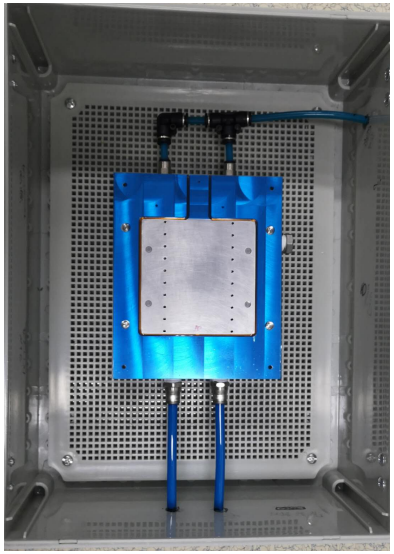
Target glue thickness is 120+/-40um.

Electrical Tests in IHEP

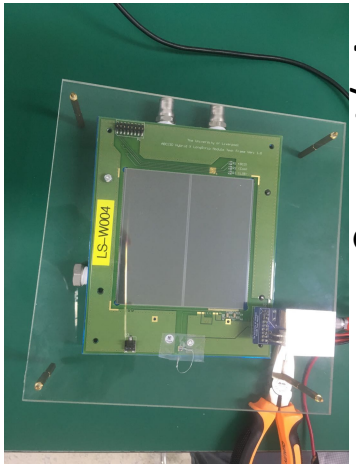
- Setup test system
- DAQLoad test single ABC130 chip
- Wire bonding the LS sensor to test frame (W003, W004)
- Sensor I-V scan
- Electrical test box: structure, humidity/temperature monitor et al
- Finish the 1st version of electrical test tutorials



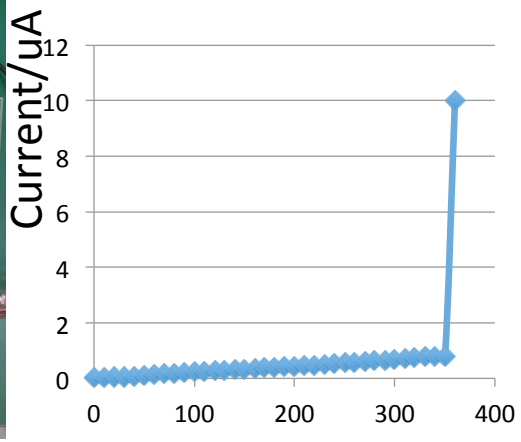
DAQLoad



Electric test box



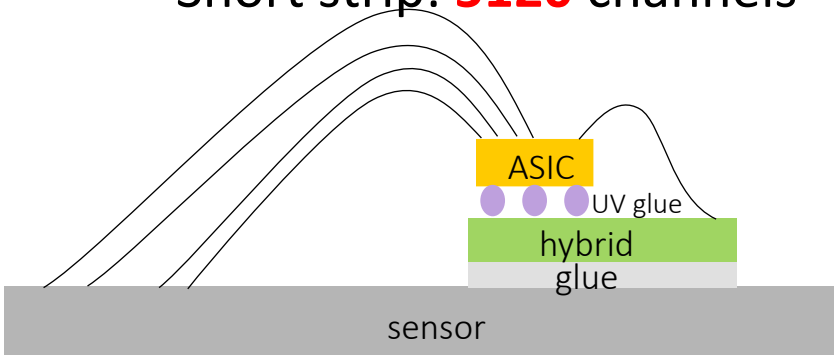
LS sensor under test

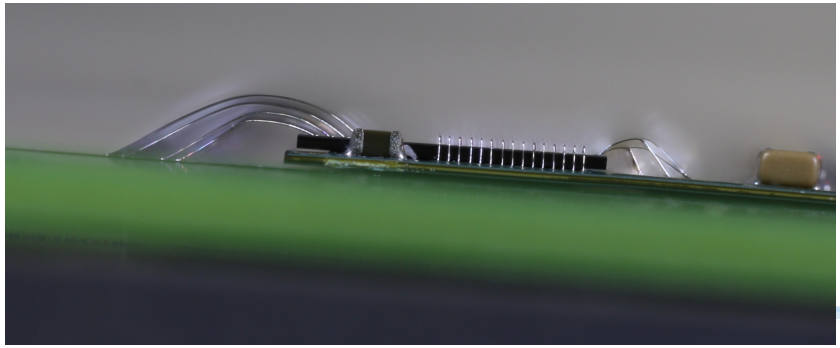


I-V of W004

Wire bonding

- To connect the circuit of strip to readout and data/power supply and control, wire bonding is an important process for module production.
- 25um aluminum wire, 60um x 200um bond pad size on ASIC
- 4-row front-end bonded from sensor to readout
  - Long strip: **2560** channels
  - Short strip: **5120** channels

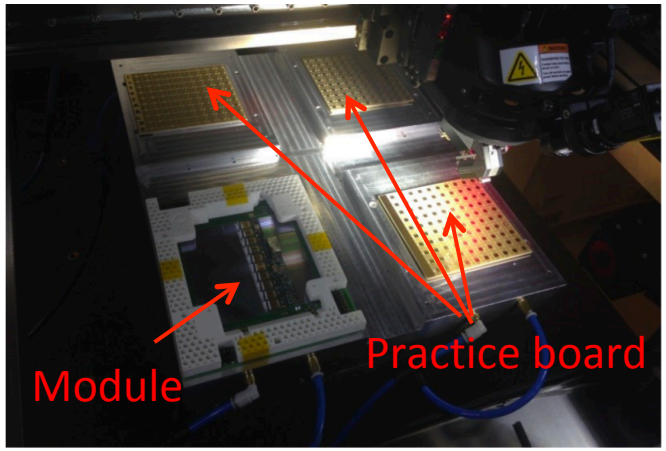


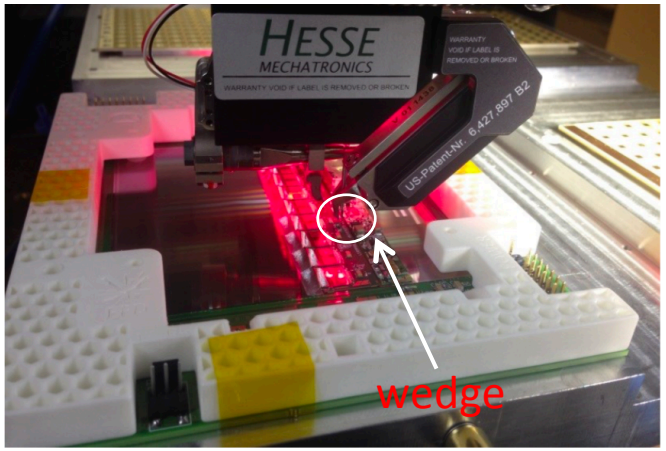


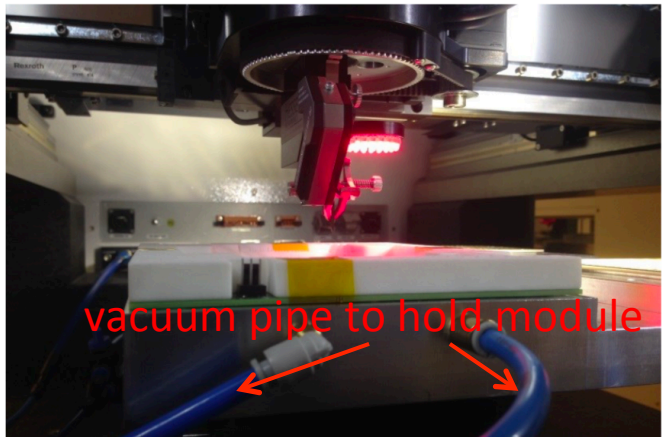
- IHEP will buy bond testing machine: DAGE 4000plus
- Study the effect of parameters
- Optimize main parameters:
  - Bond force
  - Ultrasonic
  - Deformation
  - Loop shape and height
- Wire bonding 8 hybrids and 5 modules at RAL, and pass electric test.

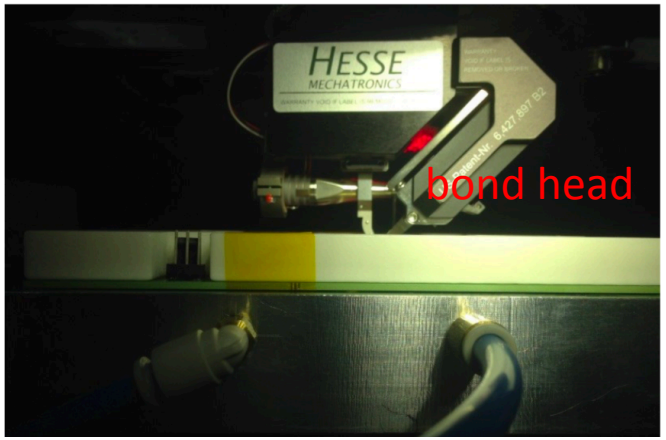
Improve wire bonding efficiency

- Developed 2x2 jig: One module each time → 4 module each time
- Optimize bonding program: pattern search works well for each module
- Need to update our BondJet820 work holder



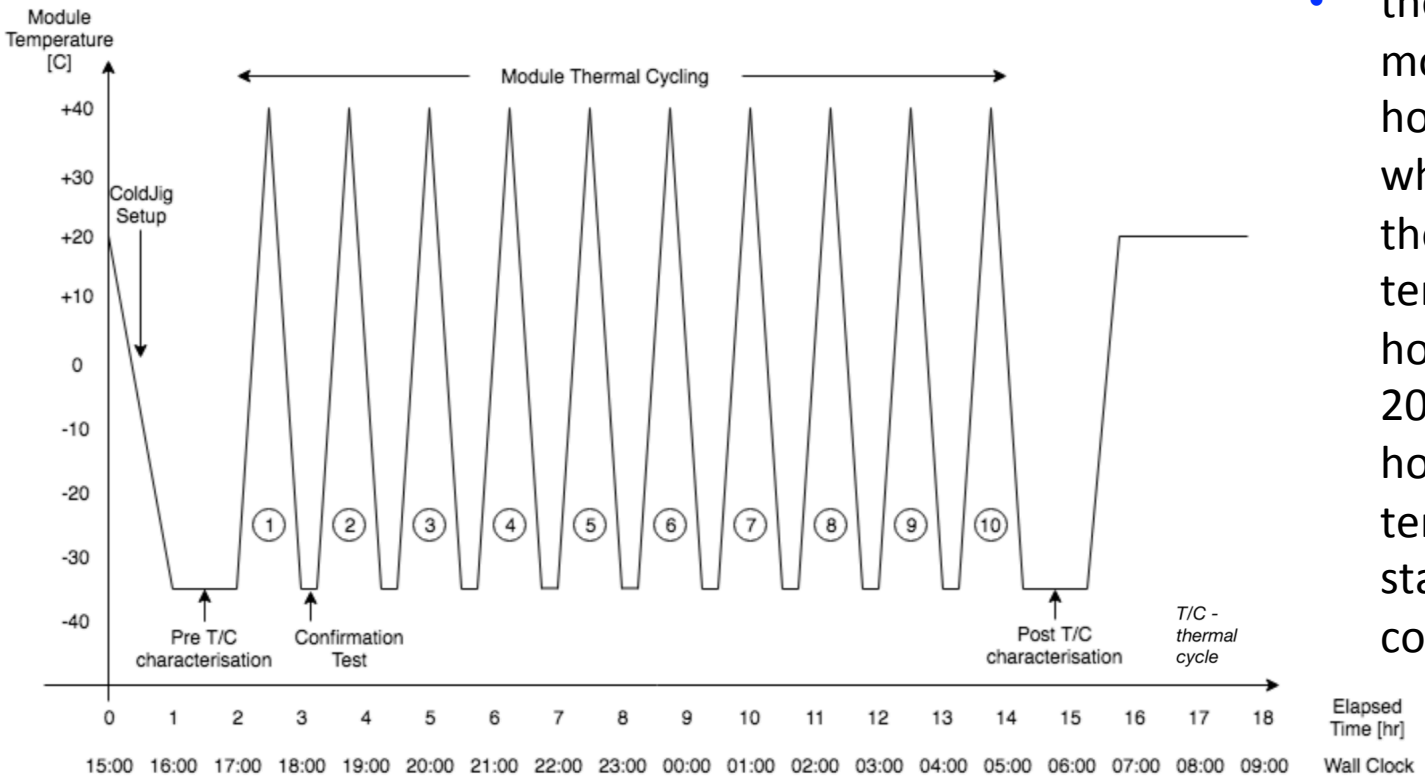






QA/QC process

Module thermal/electrical QC - timeline



The wall clock gives the time if ColdJig starts at 15:00

- Cold box
- thermal cycling for all modules: 10 cycles, 12 hours, -35°C to +40°C while powered, and then constant temperature for 2 hours at the end at 20°C, use the last two hours at constant temperature for HV stability tests, with cold turn-on test after

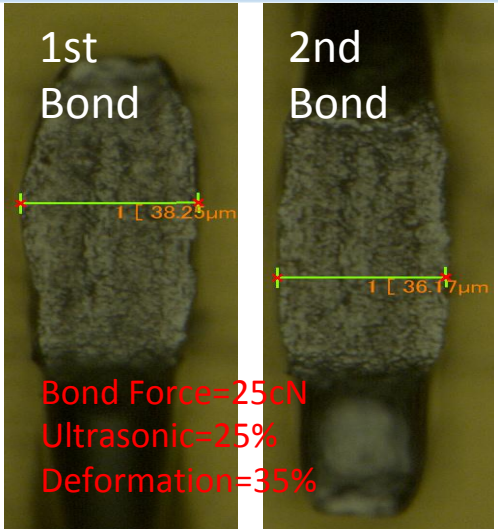
Summary

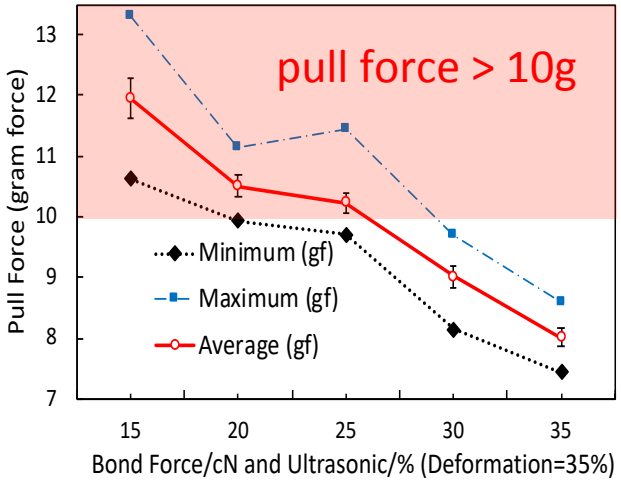
- Cooperate with RAL:
  - finished several ABC130 modules
  - participate the stave assembly
  - Attend the 1st ABCStar module prototype assembly
- IHEP:
  - Clean room ready
  - Practice ABC130 module assembly
  - Will begin ABCstar module when component are ready, will pre-production at Q1 next year.

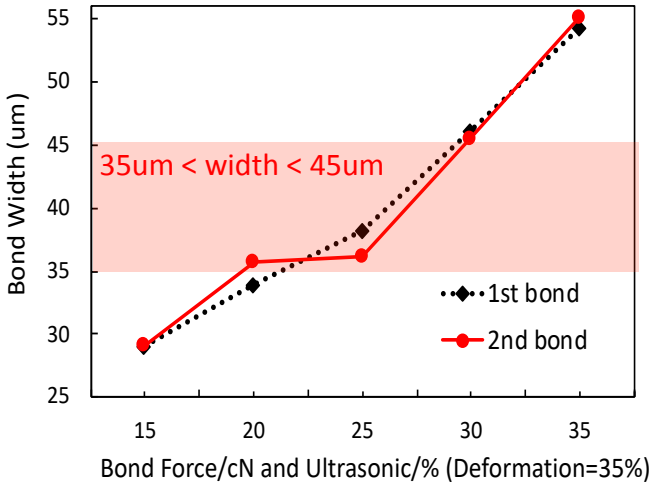
Thank you!

Back up
Optimize parameters for wire bonding

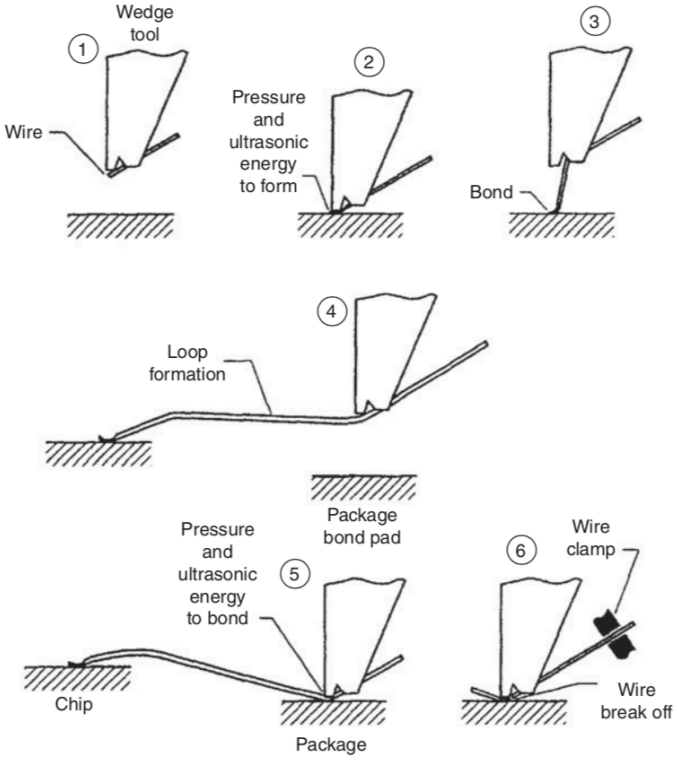
- Main parameters:
  - Bond force
  - Ultrasonic
  - Deformation
  - Tail length
  - Loop shape and height
- Wire bond testing: pull test

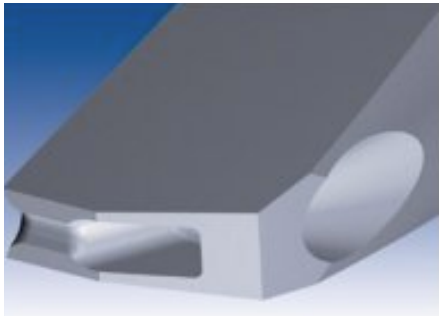




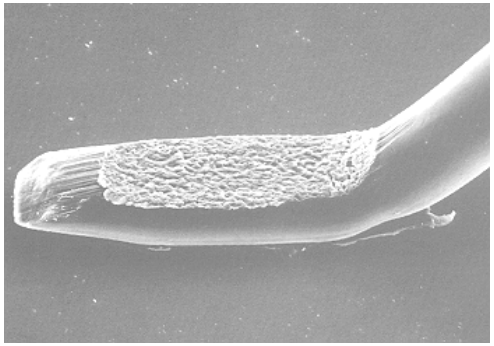


Wedge Wire Bonding

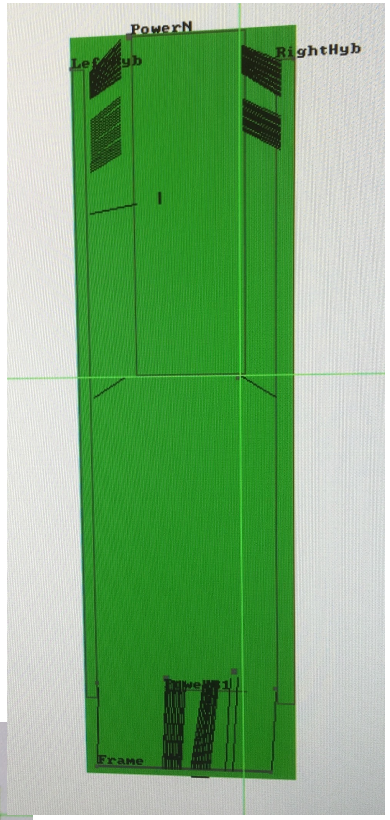


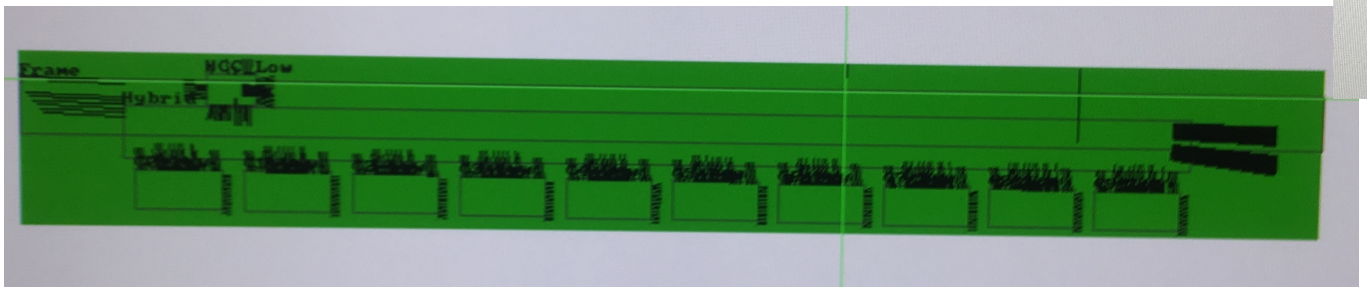


wedge



bond

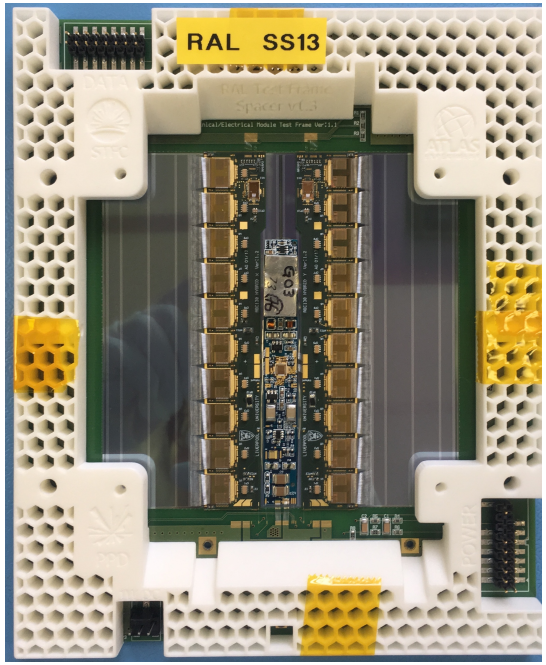




Strip module assembly in RAL

IHEP staff and postdoc located in RAL to make modules for the first double-side ABC130 Short-strip electrical stave.

- Hybrid: Metrology, ABC130 gluing, wire bonding, electrical tests
- Module: Hybrid and power board gluing, wire bonding, electrical tests



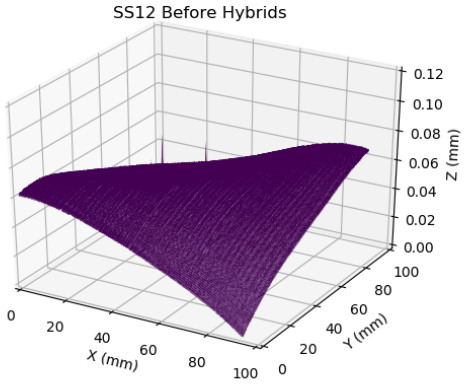
Short Strip (SS)

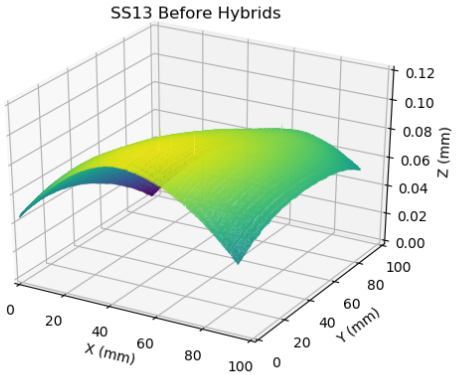
Long Strip (LS)

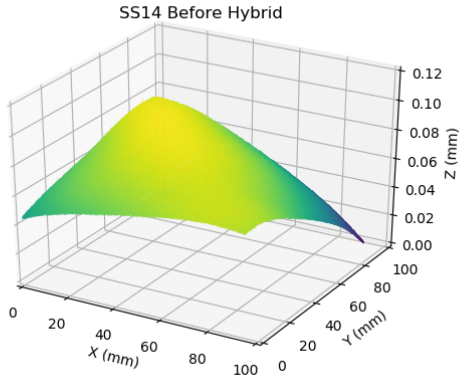
Sensor Bowing Study (at RAL)

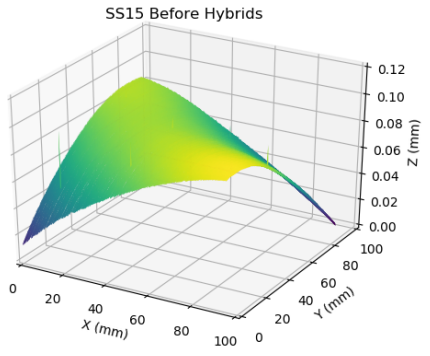
- scanned 4 Short Strip sensors before the hybrids were glued and after each one was attached

- Scanned surface using white light interferometer at 200 micron intervals in x and y directions to find height of surface
- Z resolution of less than a micron
- 225k height measurements per sensor
- Bowing between 50 and 100µm









Layer	Radius [mm]	Maximal Fluence [n_{eq}/cm^2]	Maximal Dose [MRad]
Strips			
Long Strips	762	4.2×10^{14}	10.7
Short Strips	405	8.1×10^{14}	35.7
End-cap	385	1.2×10^{15}	50.4
Pixels			
Layer 0	39	2.25×10^{16}	1710
Layer 1	75	0.82×10^{16}	715
Layer 2	155	0.25×10^{16}	148
Layer 3	213	0.12×10^{16}	96
Layer 4	271	0.12×10^{16}	61
End-cap	80	0.67×10^{16}	687